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URAL CLAYS FOR BUILDING BRICK PRODUCTION

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The chemical-mineral composition and technological properties of two varieties of low-melting clays used in production of building brick are investigated. It is found that based on the blend of these types of clay and using metallurgical slag as an additive, it is possible to obtain a ceramic mixture with minimum drying sensitivity and mechanical strength after firing at a temperature of 950°C at least equal to 12.5 MPa.

The main material for production of clay brick is low-melting clay. Low-melting clay from the Urals is usually formed by montmorillonite and exhibits high sensitivity to drying that can be reduced by introduction of grogs or clays of different mineral composition [1, 2].

The present investigation was carried out for a Ural company. Two types of clay were investigated: rich and lean clay. Slag from Niznetagislkii Iron-and-Steel Works was used as an additive. The chemical composition of the initial materials is given in Table 1. The content of free SiO_2 in the clay was determined from the dilatometric curves.

The rich clay is a semi-acid clay with a high content of coloring oxides and an average (14.5%) content of free silica. The lean clay is acid with a high content of coloring oxides and free (30.3%) silica. It has a substantial amount of carbonates.

In order to determine the mineralogical composition of clays, differential thermal (DTA) analysis was carried out.

The deep endothermic effect at 570°C seen on the thermogram (TG) of the loam is caused by removal of chemically bound water from kaolinite, and the exothermic effect at 955°C is produced by transformation of the metakaolinite lattice into primary mullite. The endothermic maximum at 120°C is caused by removal of adsorption water from hydromica and hydrohematite, and the weak exothermic effect at 355°C is due to oxidation of iron compounds. The activation energy of removal of adsorption and chemically bound water from kaolinite calculated according to the data in [3] is 28 and 115 kJ/mole, respectively.

The thermogram of the lean clay is typical of montmorillonite material. The deep endothermic effect at 140°C is conditioned by removal of adsorption water, and the similar effect at 535°C is caused by removal of chemically bound water from montmorillonite [3 – 6]. The activation energy of these processes is 37 and 87 kJ/mole, respectively. The exothermic maximum at 325°C results from oxidation of iron impurities, and the endothermic effect at 845°C is caused by decomposition of carbonates. The weak endothermic effect at 565°C is evidence of an insignificant content of kaolinite in the lean clay.

The dilatometric analysis of clay samples, both raw and previously fired at 950°C, supports the results of the chemical and mineralogical analysis (Fig. 2). The dilatograms of samples subjected to preliminary firing make it possible to determine their content of free SiO_2. The dilatograms of raw samples are typical of clay of the mineral composition specified above. The natural course of thermal expansion curves is altered under the effect of the processes related to lattice deformation on removal of interstitial water from montmorillonite, inversion of silica, and sintering of the material.

As seen in Fig. 2*b*, thermal expansion of the clays investigated at temperatures above 80°C is replaced by slight shrinking of the rich sample in the interval of 80 – 180°C, and substantial shrinking of the lean clay sample (~ 1.5%)

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TABLE 1

Material	Mass content, %*								
	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	TiO_2	loss after calcination
Clay:									
rich	$\frac{46.30}{51.39}$	$\frac{24.20}{26.86}$	$\frac{0.37}{0.41}$	$\frac{1.76}{1.95}$	$\frac{0.82}{0.91}$	$\frac{2.75}{3.05}$	$\frac{11.98}{13.30}$	$\frac{1.29}{1.43}$	$\frac{9.99}{-}$
lean	$\frac{57.10}{62.24}$	$\frac{13.50}{14.71}$	$\frac{2.34}{2.55}$	$\frac{3.75}{4.09}$	$\frac{1.51}{1.65}$	$\frac{1.65}{1.80}$	$\frac{9.38}{10.22}$	$\frac{0.92}{1.00}$	$\frac{8.12}{-}$
Slag	40.10	12.48	40.44	5.03	0.60	0.76	0.50	–	0.08

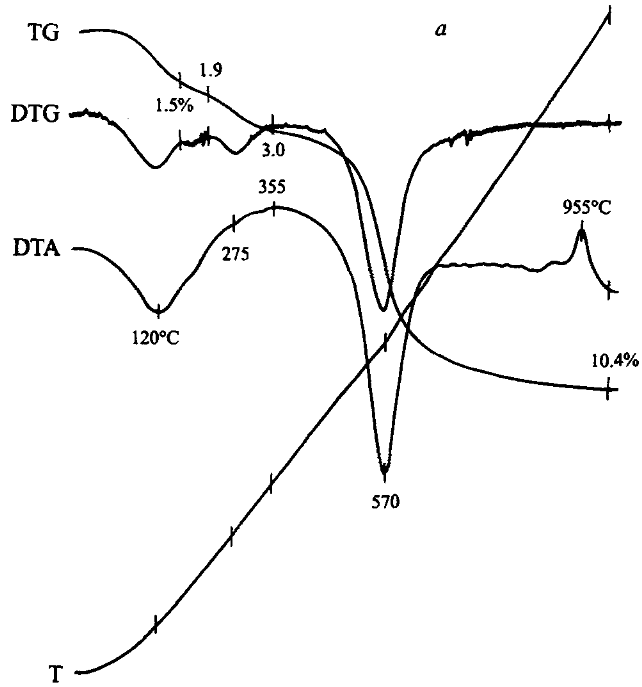

Fig. 1. Thermograms of rich (*a*) and lean clay (*b*).

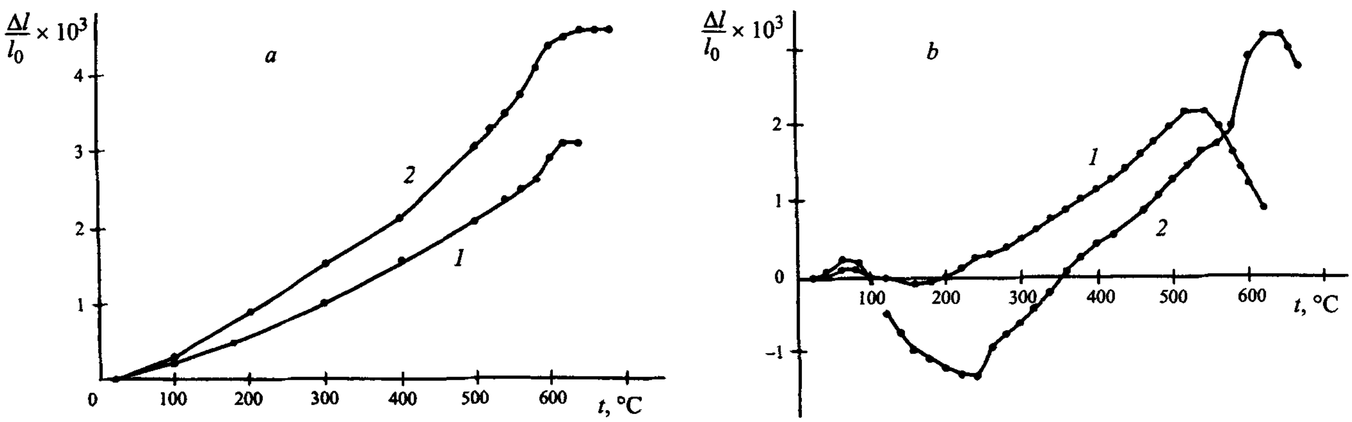

Fig. 2. Dilatograms of rich (*1*) and lean clay (*2*) after firing at 950°C (*a*) and in the natural state (*b*).

in the interval of 80 – 240°C. Expansion of the rich clay owing to silica inversion is compensated by the processes accompanying formation of metakaolinite at a temperature of 560°C. The dilatogram of the lean clay containing plenty of free silica shows that quartz inversion within the interval of 560 – 600°C dramatically increases the sample expansion at temperatures above 620°C and is followed by its shrinkage associated with sintering of the sample.

Thus, rich clay has a hydromica-kaolinite composition, and lean clay is formed by montmorillonite. The mineral composition of the impurities in both clays is the same: hydrohematite, feldspar, rutile, talc, and in addition, carbonates in the lean clay.

The clays exhibit a low content of coarse-grain inclusions: 2.5 and 5.3% in loam and lean clay, respectively. As for the content of finely disperse fractions, the rich clay is medium-disperse, and the lean clay is coarsely disperse. The clay density in the natural state and after firing at 950°C was 2.55 and 2.67 g/cm^3 for the rich clay, and 2.50 and 2.80 g/cm^3 for the lean clay, respectively. The plasticity (according to Vasil'ev) was 14 in the rich and 12 in the lean clay. The rich clay has high drying sensitivity (0.22), and the lean clay has medium drying sensitivity (1).

The high drying sensitivity of the rich clay prevents its independent use in production of construction ceramics. In order to reduce the drying sensitivity, mixtures of the clays in

TABLE 2

Parameter	Mixture lean	rich	1	2
After firing at 950°C				
Shrinkage, %:				
air shrinkage	2.2	2.7	–	–
total shrinkage	3.7	8.7	5.5	5.6
Water absorption, %	19.5	11.4	12.8	13.3
Porosity, %	33.0	23.2	25.2	26.0
Apparent density, %	1.69	2.03	1.96	1.95
Strength, MPa:				
bending strength	6.0	4.4	6.5	8.1
compressive strength	5.0	12.9	12.0	12.5
After firing at the temperature of 1050°C				
Total shrinkage, %	4.9	9.6	7.2	7.0
Water absorption, %	9.4	4.0	9.8	10.6
Porosity, %	19.4	9.3	20.4	21.6
Apparent density, %	2.08	2.32	2.07	2.05
Strength, MPa:				
bending strength	8.1	7.5	9.2	8.4
compressive strength	8.5	12.0	12.5	12.5

various ratios were prepared. The best results were obtained for the samples containing lean clay and rich clay in the ratio of 70 : 30 and 80 : 20 (mixtures 1 and 2, respectively). These mixtures exhibit low drying sensitivity (0.73 for mixture 1 and 0.82 for mixture 2).

In order to determine the ceramic characteristics, the samples were molded plastically from rich and lean clay, as well as from mixtures 1 and 2, and after drying were fired at temperatures of 950 and 1050°C. Mixtures 1 and 2 contain 7% metallurgical slag as a sintering additive. The properties of the samples after firing are presented in Table 2.

The rich clay sinters poorly, and its samples have low mechanical strength even after firing at 1050°C.

Samples made of mixtures 1 and 2 after firing have a smooth surface without cracks, and homogeneous color. Their qualitative parameters make it possible to recommend compositions with addition of metallurgical slag for production of grade 125 Clay brick.

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